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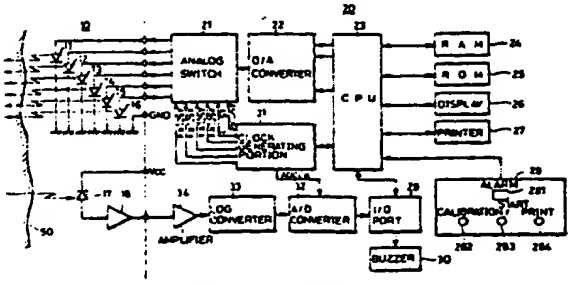
(54) Reflection type oximeter.

(57) A reflection type oximeter comprises light emitting diodes (11 to 16) as first to sixth light sources which emit first and second beams of a wavelength involving a change in absorption due to a change in oxygen saturation of hemoglobin in blood of a tissue of a living body, third and fourth beams of another wavelength involving no change in absorption, and fifth and sixth beams of a further wavelength involving a relatively small change in absorption due to changes in a quantity of hemoglobin and oxygen saturation. Those beams are applied to the tissue (50) of the living body and the beams of the first to sixth light sources reflected therefrom are received by a light receiving element (17). Intensities of the beams emitted from the light emitting diodes are set to predetermined levels and the intensities of the beams received by the light receiving element are evaluated by a CPU (23) and, based on a predetermined function, the quantity of hemoglobin and the oxygen saturation of the tissue are evaluated. Those evaluated values are displayed on a display portion (26) and printed by a printer (27).

FIG.1



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Reflection Type Oximeter

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a reflection type oximeter. More particularly, the present invention relates a reflection type oximeter in which light pulses are applied to tissue of a living body to measure oxygen saturation or the like in an non-invasive manner based on reflected light therefrom.

Description of the Prior Art

A conventional optical oximeter is known as an apparatus for measuring oxygen saturation in arterial blood based on light transmitted through the finger, the ear or the like of a person to be examined, when light is applied thereto.

Several examples of the prior art will be described in the following. One of them is the United States Patent No. 2,706,927. This apparatus evaluates oxygen saturation based on measured values of absorbance of each of two different wavelengths in two states, i.e., a state in which the ear is pressed and congested and a state in which the pressure on the ear is relieved. The measured value in the congested state is based on only absorbant components other than the blood and the measured value in the non-pressed state is based on both of the blood and the other absorbant elements. Therefore, the absorbance of only the blood should be indicated by comparison between the read values in the two states. On the other hand, the precision of the measured value would be lowered without fail. The reasons are that all the blood cannot be removed if the ear is pressed and that an optical connection between the ear and the optical apparatus varies. In addition, influence of the absorbant components due to differences in color of the skin and the thickness for example is considerably different dependent on the respective persons to be examined and, accordingly, it is necessary to effect calibration for each person or each measured value.

The second conventional example is the United States Patent No. 3,638,610. In this example, the above described defect is removed by utilization of measured values of absorbance based on a plurality of wavelengths of light. Similarly to all the conventional apparatuses, the good result obtained by this apparatus depends on an increase of perfusion in the living body examined. For that reason, the perfusion in the living body is made to be as closest to the arterial blood as possible. The perfusion can be increased artificially until an accurate result can be obtained. However, such method is often unfavorable or very difficult dependent on the conditions of the person examined.

The third conventional example is an oximeter disclosed in Japanese Patent Laying-Open Gazette No. 88778/1978. This oximeter has the below described features. Light of one wavelength and light of another wavelength are applied successively to the fingers, the earlobes or other parts of a living body. This oximeter comprises photodetector means which generates a first electric signal proportional to part of light of a wavelength absorbed in such part of the body and generates a second electric signal proportional to part of light of another wavelength in that part. When the heart sends a larger quantity of blood to the artery tissue than that at pause thereof, a larger quantity of blood exists in that part of the body and accordingly the lights of the two wavelengths are more attenuated than in the pause state of the heart. Consequently, the first and second electric signals have peaks of the maximum and minimum values in one pulse period of the heart. A difference of the maximum and minimum peak values entirely depends on pulsating current of blood, while the pulse period is not at all influenced by the absorbant component which attenuates light by a given quantity.

However, measurement is not permitted in a part where blood current of artery is not obtained or a part where a cuvette necessary for detection of transmitted light cannot be attached.

The fourth conventional example is an oximeter disclosed in Japanese Patent Laying-Open No. 51785/1977. This is a reflection type oximeter which can be attach d to a part of a living body without a cuvette required in the above described first to third exampl s. However, this oximeter is used in principle for detection of a pulsation component and accordingly it is impossible to make measurement if the pulsation component is not obtained.

Still another conventional exampl is a pulse oximeter disclosed in Japanese Patent Laying-Open No. 160445/1984. In this oximeter, a pulsation component of the blood current of the artery is detected as a

change of a transmitted light component of the light applied to the tissue, whereby oxygen saturation in the arterial blood is measured. Consequently, the following disadvantages are involved.

Such an oximeter is incapable of making measurements in a part or a state where a pulsation component does not exist. The object which can be measured are only an oxygen saturation degree and a quantity of hemoglobin and the apparatus is incapabl of measuring tissue oxygen saturation including information of venous blood serving as an index representing metabolism of the tissue. Since it utilizes transmitting and absorbing functions of the mechanism, it can be attached only to a part used as an optical cell. In addition, since a transmission path of light is not clearly known, it is not clear as to which part (volume) the information detected concerns. Further, noise occurs due to sway or vibration of the sensor.

SUMMARY OF THE INVENTION

Therefore, a primary object of the present invention is to provide a reflection type oximeter which can overcome the above described disadvantages and which is capable of evaluating functions of the lung or the heart of a living body or a state of oxygen supplied to the tissue of the body, and capable of continuously monitoring conditions of a patient for a long period.

Briefly stated, the present invention performs operation in the following manner. First and second beams of a wavelength subjected to a change in absorbance due to a change in oxygen saturation of hemoglobin in blood of tissue of a living body, third and fourth beams of another wavelength not subjected to any change in absorbance, and fifth and sixth beams of a further wavelength subjected to a relatively small change in absorbance due to changes in a quantity of hemoglobin and oxygen saturation are applied to the tissue of the body, and light receiving means receives the first to sixth beams reflected from th tissue of the body. Intensities of the respective outputs of the light receiving means are evaluated and, based on a predetermined function, the quantity of hemoglobin in the tissue is calculated and the result of the calculation is outputted.

Consequently, the present invention makes it possible to dissolve various problems in the conventional non-invasive type oximeters, such as incapability of measurement in a part where a pulsation component does not exist, measurement limited only to oxygen saturation in artery, noise due to sway or vibration of a sensor, and incapability of measurement without an optical cuvette because of an optical transmission method. Accordingly, the oximeter of the present invention is capable of evaluating lung functions, heart functions, a state of oxygen supplied to tissue, and other data in examinations of anesthesiology, dermatology, pediatrics etc., and is also capable of continuously monitoring conditions of a patient for a long period.

In a preferred embodiment of the present invention, a calibration mode and a measurement mode can be selected and when the calibration mode is selected, a voltage to be applied to light source means is set so that intensity of light emitted from the light source means is within a predetermined range.

Consequently, according to the above-mentioned preferred embodiment of the present invention, intensity of light emitted from the light source means is calibrated prior to measurement and a quantity of hemoglobin in tissue of the body can be measured more accurately.

In another preferred embodiment of the present invention, assuming that intensities of the first, second, third, fourth, fifth and sixth beams reflected from the tissue are P1, P2, P3, P4, P5 and P6, the quantity of hemoglobin in the tissue is calculated by:

$$C1\ [\log(P3/P4)]^2 + C2\log(P3/P4) + C3$$

where C1, C2 and C3 are correction values.

In addition, in a further preferred embodiment of the present invention, the light source means is formed by first to sixth light sources emitting the first to sixth beams, respectively, and the first, third and fifth light sources are located at positions distant from the center of the light receiving means by a predetermined distance d1, while the second, fourth and sixth light sources are located at positions distant from the center of the light receiving means by a predetermined distance d2, with a relation of d1 < d2 being maintained.

In another asp ct of the present invention, first and second b ams of a wavelength subjected to a change in absorbance due to a change in oxygen saturation of hemoglobin in blood of tissue of a living body, third and fourth beams of another wavelength not subjected to any chang in absorbance, and fifth and sixth beams of a further wav length subjected to a relatively small chang in absorbance due to a change in oxygen saturation are applied to the tissue of the body and the first to sixth beams reflected therefrom are detected, whereby int nsiti s of the r spective beams are evaluated and the oxygen

saturation of the tissue is evaluated based on a predetermined function.

Consequently, according to this aspect of the invention, it becomes possible to measure oxygen saturation in a part not containing a pulsation component, which could not be measured in a conventional apparatus.

These objects and other objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic block diagram of an embodiment of the present invention.

Fig. 2A is a plan view of a sensor portion shown in Fig. 1.

Fig. 2B is a sectional view taken along the line IIB-IIB shown in Fig. 2A.

Fig. 3 is a timing chart for detection of amounts of beams reflected from an object to be measured, having wavelengths λ1, λ2 and λ3.

Fig. 4 is a diagram showing data stored in a RAM shown in Fig. 1.

Figs. 5 to 7 are flowcharts for explaining concrete operation of the embodiment of the present invention. Particularly, Fig. 5 shows a data sample subroutine, Fig. 6 shows a calibration mode, and Fig. 7 shows a measurement mode.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

First referring to Figs. 2A to 2B, a principle of the present invention will be described. A sensor portion 10 comprises a first light source 11, a second light source 12, a third light source 13, a fourth light source 14, a fifth light source 15, a sixth light source 16, a light receiving element 17 and a preamplifier 18, which are integrally formed as a unitary body disposed on a black ceramic substrate 100. Light emitting diodes are used as first to sixth light sources 11 to 16. The light emitting diodes 11 and 12 emit light of a wavelength λ1 (for example, 660nm), the absorbance of which is considerably changed due to a change in oxygen saturation in blood. The light emitting diodes 13 and 14 emit light of a wavelength λ2 (for example, 805nm), the absorbance of which undergoes substantially no change due to a change in oxygen saturation of hemoglobin. The light emitting diodes 15 and 16 emit light of a wavelength λ3 (for example, 940nm), the absorbance of which is changed to a relatively small extent due to changes in oxygen saturation of hemoglobin and the quantity of hemoglobin. The light emitting diodes 11, 13 and 15 are located at positions apart from the center of the light receiving element 17 by a distance d1 and the light emitting diodes 12, 14 and 16 are located at positions apart from the center of the light receiving element 17 by a distance d2, with a relation of d1 < d2 being maintained.

There is provided a light interception wall 19 which surrounds the light sources 11 to 16, the light receiving element 17 and the preamplifier 18, and separates the light sources 11 to 16 from the light receiving element 17, thereby to prevent incidence of external light on the light receiving element 17 and to prevent direct application of light from the light sources 11 to 16 to the light receiving element 17. The partition wall which separates the light sources 11 to 16 from the light receiving element 17 has a thickness of 0.5mm or less for example and a height of about 0.8mm for example. The wall 19 also serves to prev nt resin material 101 (of epoxy, urethane, silicone or the like) introduced onto the light sources 11 to 16 and the light receiving element 17 from flowing outside the wall. A relay electrode 102 is formed between the light sources 11, 13 and 15 and the light sources 12, 14 and 16. The relay electrode 102 comprises a copper film formed on the black ceramic substrate 100 and it serves to distribute electric power supplied from outside the sensor portion 10 to the respective light sources 11 to 16. Electric current is supplied from the relay electrode 102 to the respective light sources 11 to 16 through boding wires 103 and the current is fed back through a printing circuit for example formed on the black ceramic substrate 100.

A detailed description of transmission of light in the sensor portion 10 thus constructed is given for example in a document "Photon Diffusion Theory" published by Takaya et al. This theory will be concr tely described as follows. The sensor portion 10 is attached to a part of a human body, for example, a fingertip and the light sources 11 to 16 are caused to emit beams successively, so that a plurality of light sources may not emit beams concurrently. The beams emitted from the light sources 11, 13 and 15 near the light receiving element 17 are diffused and refl cted in th tissue of the body and attain the light receiving element 17 as shown by arrows in Fig. 2B. Intensities of the b ams received in the light receiving element

17 are represented as P1, P3 and P5. The beams emitted from the light sources 12, 14 and 16 distant from the light receiving element 17 are also diffused and reflected in the tissue of the body and attain the light receiving element 17. Intensities of the beams thus received are represented as P2, P4 and P6. The intensities P1, P3 and P5 and the intensities P2, P4 and P6 are obtained through different transmission paths and include different amounts of information. Let us consid r the paths of the reflected beams referring to Fig. 2B. Transmission of the beams is specifically applied according to the above described photon diffusion theory and the intensities of P2, P4 and P6 have information of a deeper part than th information of the intensities of P1, P3 and P5. Therefore, as shown in Fig. 2B, it is assumed that a region sampled by the intensities of the received beams P1, P3 and P5 is a first layer 40, that a region sampled by the intensities of the received beams P2, P4 and P6 is a second layer 50 and that characteristics given at the time of transmission of the beams in the respective layers are represented as $\alpha 11$ and $\alpha 12$. It is assumed in this case that the characteristics $\alpha 11$ and $\alpha 12$ depend on the transmission, absorption or scattering of the beams from the light sources, hemoglobin existing in the tissue and the like. If intensities of the beams emitted from the light sources 11 and 12 are represented as I1 and I1', respectively, th received light amounts P1 and P2 are represented in the following simplified manner:

$$P1 = I1\,\alpha 11$$
$$P2 = I1'\,\alpha 11\,\alpha 12 \qquad (1)$$

If a ratio between the intensities of the received beams P1 and P2 is considered, it is represented by the following equation (2).

$$\frac{P2}{P1} = \frac{I1' \cdot \alpha 11}{I1 \cdot \alpha 11 \cdot \alpha 12} \qquad \cdots (2)$$

If I1 = I1', that is, the intensities of the emitted beams are equal, the above stated equation (2) is represented by the following equation (3)

$$P2/P1 = 1/\alpha 12 \qquad (3)$$

According to the equation (3), the component of the first layer 40 is removed. This means that only th component of the second layer 50 is detected according to the equation (3). If, for example, the distance d1 (between the light sources 11, 13 and 15 and the light receiving element 17) is set to obtain, as the component of the first layer 40, information of a capillary layer liable to cause disturbance in bloodstream when it is pressed by the sensor attached and the distance d2 (between the light sources 12, 14 and 16 and the light receiving element 17) is set to obtain, as the component of the second layer 50, information of a bottom of blood hardly subjected to disturbance when it is pressed by the sensor attached, an artifact due to disturbance in bloodstream, which was a problem to be solved in the prior art, can be removed.

At the same time, skin may be considered as being included in the first layer 40 and an individual difference such as a difference of color of the skin can be also dissolved by applying the above described principle.

Similarly, the above described principle is also applied to the two groups of light sources 13, 14, 15 and 16 having the different wavelengths $\lambda 2$ and $\lambda 3$ of light and the following equations are obtained.

$$\frac{P4}{P3} = \frac{I2' \cdot \alpha 21}{I2 \cdot \alpha 21 \cdot \alpha 22} \qquad \cdots (4)$$

$$\frac{P6}{P5} = \frac{I3' \cdot \alpha 31}{I3 \cdot \alpha 31 \cdot \alpha 32} \qquad \cdots (5)$$

In addition if I2' = I2 and I3' = I3, the following equations are obtained.

$$\frac{P4}{P3} = \frac{1}{\alpha 22}, \quad \frac{P6}{P5} = \frac{1}{\alpha 32} \qquad \ldots (6)$$

Thus, it is understood that an artifact influenced by disturbance in bloodstream and an individual difference of the skin can be removed in the same manner as in the case of the wavelength λ1.

It is indicated by Takayama et al. for example that the quantity of hemoglobin (Hb_T) in the tissue of the living body is obtained in the following manner.

$$Hb_T = C1[\ln(1/R)]^2 + C2[\ln(1/R)] + C3 \qquad (7)$$

where R is an intensity of light reflected from the tissue, having a wavelength not causing any change in absorbance due to change in oxygen saturation of hemoglobin and C1, C2 and C3 are coefficients set at the time of calibration. Now, if the principle of the present invention is applied to the above described equation (7), the following equation (8) can be considered.

$$Hb_T = D1\ [\log(P3/P4)]^2 + D2\ [\log\ \{P3/P4)] + D3 \qquad (8)$$

where D1, D2 and D3 are coefficients set at the time of calibration.

From the above-mentioned equation (8), it becomes possible to determine and measure the quantity of hemoglobin (Hb_T) in the tissue of the living body by removing the artifact caused by disturbance in bloodstream due to the pressure of the sensor attached or the individual difference of the color of the skin.

The oxygen saturation (S_{02T}) of the tissue is expressed by the following equation (9).

$$S_{02T} = A - B \times \log\left(\frac{P1/P2}{P5/P6}\right) \Big/ \log\left(\frac{P3/P4}{P5/P6}\right) \qquad \ldots (9)$$

where A and B are coefficients set at the time of calibration. In this case also, the theory represented by the above-mentioned equation (6) is applied and it becomes possible to make stable measurement by removing the artifact caused by disturbance in bloodstream by pressure of the attached sensor or the individual difference of the color of the skin.

In the following, the embodiment of the present invention will be described based on the above described principle.

Fig. 1 is a schematic block diagram of the embodiment. First, construction of this embodiment will be described. In Fig. 1, a reflection type oximeter comprises the sensor portion 10 described above with reference to Figs. 2A and 2B, and a measurement processing portion 20. The sensor portion 10 comprises the first to sixth light sources 11 to 16, the light receiving element 17 and the preamplifier 18 as described previously. The light sources 11 to 16 are driven by the measurement processing portion 20 so that they emit light successively by pulse operation.

The measurement processing portion 20 comprises a central processing unit (CPU) 23 as evaluation means. The CPU 23 supplies, to a D/A converter 22, data for controlling intensities of light pulses emitted from the light sources 11 to 16. The D/A converter 22 converts the data to an analog signal, which is supplied to an analog switch 21. The analog switch 21 comprises six switching elements which are operated by clock signals ASCCKL1, 2, 3, 4, 5 and 6 supplied from a clock generator 31, so that an output of the D/A converter 22 is supplied to the light sources 11 to 16. An output of the light receiving element 17 is supplied to an amplifier 34 through the preamplifier 18, so that it is amplified. An output of the amplification is supplied to a LOG converter 33 so as to be logarithmically converted. An output of the LOG converter 33 is sampled by an A/D converter 32 and outputted as a digital signal. The digital signal is supplied to the CPU 23 through an I/O port 29. The A/D converter 32 receives a clock signal ADCLK from th clock generator 31. Th I/O port 29 is connected with a buzzer 30. The buzzer 30 is used to issue an alarm when a result of measur ment considerably deviates from a normal valu .

Further, the CPU 23 is connected with a RAM 24, a ROM 25, a display portion 26, a printer 27, and an operation portion 28. The RAM 24 stores various data as shown in Fig. 4 as described later. The ROM 25 stores programs based on flowcharts shown in Figs. 5 to 7. Th display portion 26 displays a result of evaluation of the CPU 23 and the print r 27 prints the result of evaluation.

The operation portion 28 includes an alarm LED 281, a calibration key 282, a start key 283 and a print

key 284. The alarm LED 281 displays an alarm when a result of calculation has a low reliability. The calibration key 282 is used to set a calibration mode. The start key 283 instructs a start of a measurement mode and the print key 284 instructs a printout of the result of calculation.

Fig. 3 is a timing chart for detection of intensities of the beams of the wavelengths λ1, λ2 and λ3 transmitted through an object to b measured. Fig. 4 is a diagram showing data stored in the RAM shown in Fig. 1. Figs. 5 to 7 are flowcharts for explaining concrete operation of the embodiment of the present invention. Particularly, Fig. 5 shows a data sample subroutine; Fig. 6 shows the calibration mode; and Fig. 7 shows the measurement mode.

Referring now to Figs. 1 to 7, concrete operation of the embodiment will be described. First, the steps SP1 to SP24 shown in Fig. 5 are procedures for sampling the intensities of the beams of the wavelengths λ1, λ2 and λ3 transmitted through the object to be examined and storing them in areas 241 to 246 of the RAM 24.

More specifically, in the step SP1, the CPU 23 reads data of a drive voltage V_{L1} of the first light source 11 stored in a storage area 256 of the RAM 24 shown in Fig. 4 and supplies the data to the D/A converter 22. The D/A converter 22 converts the data of the voltage to an analog signal and supplies it to the analog switch 21. The analog switch 21 receives the clock signal ASCLK1 as shown in (i) of Fig. 3 from the clock generator 31. In the step SP2, the analog switch 21 is turned on in response to the clock signal ASCLK1 and supplies, to the first light source 11, the analog voltage V_{L1} converted by the D/A converter 22. Then, the first light source 11 emits light of an intensity corresponding to the drive voltage V_{L1} and applies it to the object 50 to be examined.

The emitted light is reflected on the object 50 and is received by the light receiving element 17. The light receiving element 17 converts the received light to an electric signal and supplies it to the amplifier 34 through the preamplifier 18. The amplifier 34 amplifies the signal and supplies it to the LOG converter 33 so that it is logarithmically converted. The logarithmically converted voltage is supplied to the D/A convert r 32. The clock signal ADCLK as shown in (g) of Fig. 3 is applied from the clock generator 31 to the A/D converter 32. Accordingly, in the step SP3, the A/D converter 32 converts the analog output of the LOG converter 33 to a digital output based on the clock signal ADCLK. The digital output is supplied to the CPU 23 through the I/O port 29. In the step SP4, the CPU 23 reads the output of the A/D conversion and stores it as P1 in the area 241 of the RAM 24.

Similarly, the CPU 23 reads data of a drive voltage V_{L2} of the second light source shown in (b) of Fig. 3 stored in the area 257 of the RAM 24 and supplies it to the analog switch 21 through the D/A converter 22. The clock signal ASCLK2 2 as shown in (j) of Fig. 3 is applied from the clock generator 31 to the analog switch 21. Accordingly, in the step SP6, the analog switch 21 is turned on based on the clock signal ASCLK2 to supply the drive voltage V_{L2} to the second light source 12. Then, the second light source 12 emits light of an intensity corresponding to the drive voltage V_{L2} and applies it to the object 50 to b examined. The emitted light of the wavelength λ1 is reflected on the object 50 and is received by the light receiving element 17.

The light receiving element 17 photoelectrically converts the received light and supplies it to the amplifier 34 through the preamplifier 18. The output of the amplifier 34 is logarithmically converted by the LOG converter 33 in the same manner as described above and is supplied to the A/D converter 32. In th step SP7, the A/D converter 32 starts A/D conversion based on the clock signal ADCLK from the clock generator 31. An output of the A/D conversion is supplied to the CPU 23 through the I/O port 29. In the step SP8, the CPU 23 reads the output of the A/D conversion and stores it as P2 in the area 242 of the RAM 24. Subsequently, the CPU 23 performs operation in the steps SP9 to SP24, in which it drives the third to sixth light sources 13 to 16 based on data of the drive voltages V_{L3} to V_{L6} stored in the areas 258 to 261 of the RAM 24 and stores the data as P3 to P6 in the areas 243 to 246, respectively, based on the output of the light receiving element 17.

Now, the calibration mode shown in Fig. 6 will be described. The calibration mode is started when power supply of the apparatus is turned on or when operation in the measurement mode shown in Fig. 7 as described later is brought to an end. In the step SP31, the CPU 23 displays the calibration mode on the display portion 26. This display serves to indicate that the calibration mode is selected and it also serves to instruct attachment of the sensor portion 10. According to this instruction, the operator of the apparatus attaches the sensor portion 10 to the object 50 to be examined. Then, in the st p SP32, the CPU 23 waits until the calibration key 282 is operated. When the calibration key 282 is operated, the CPU 23 proceeds to the step SP 33 to x cute the data sample subroutine shown in Fig. 5.

The CPU 23 measures the data P1 to P6 by m times based on data of the number of times stored in the area 255 of the RAM 24 and stores average light data obtained by averaging the data of the measurements by m tim s as PM1 to PM6 in areas 262 to 267 of the RAM 24. The CPU 23 stores th

values of PM1 to PM6 in the areas 247 to 252 of the RAM 24 as PO1 to PO6 in the step SP34. Then, the CPU 23 executes the steps SP35 to SP57, in which the drive voltages V_{L1} to V_{L6} applied to the first to sixth light sources 11 to 16 are regulated so that PO1 to PO6 are set between the light data P_{MAX} and P_{MIN} ($P_{MAX} > P_{MIN}$) sto in the areas 253 and 254 of the RAM 24, respectively.

More specifically, in the step SP35, if PO1 is larger than P_{MAX}, the CPU 23 proceeds to the step SP36 to set the drive voltage V_{L1} to a small value. Then, the steps SP33 and SP34 are executed again and it is determined again in the step SP35 whether PO1 is larger than P_{MAX}. If PO1 is not smaller than P_{MAX}, the CPU 23 proceeds to the step SP37 to determine whether PO1 is smaller than P_{MIN}. If PO1 is smaller than P_{MIN}, the value of the drive voltage V_{L1} is increased in the step SP38 and then the CPU 23 returns to th above-mentioned step SP33. Those operations are repeated to regulate the drive voltage V_{L1} so that PO1 is set between P_{MAX} and P_{MIN}.

Subsequently, operations in the steps SP39 to SP58 are executed and the drive voltages V_{L2} to V_{L6} are regulated so that PO2 to PO6 are set between P_{MAX} and P_{MIN}. Then, the finally set drive voltages V_{L1} to V_{L6} are stored in the areas 257 to 261 of the RAM 24.

Then, the operator attaches the sensor portion 10 to a part to be examined, for example, a fingertip and operates the start key 283. In consequence, the CPU 23 proceeds to the measurement mode shown in Fig. 7. More specifically, in the step SP61, the above described data sample subroutine shown in Fig. 5 is executed and P1 to P6 based on the light pulses received from the first to sixth light sources 11 to 16, reflected on the part to be examined, are stored in the areas 241 to 246 of the RAM 24. Then, the CPU 23 substitutes P3 and P4 stored in the areas 242 and 245 of the RAM 24 into the above-mentioned equation (8) and evaluates the quantity of hemoglobin Hb_T. Further, in the step SP63, the CPU 23 substitutes P1, P2, P3, P4, P5 and P6 stored in the areas 241, 243, 244, and 246 of the RAM 24 into the above indicated equation (9) to evaluate the oxygen saturation S_{O2T} of the tissue of the body. The quantity of hemoglobin Hb_T and the oxygen saturation S_{O2T} of hemoglobin in the tissue of the body determined by the evaluation operations are displayed on the display portion 26. If the print key 284 is operated in this case, the results of the evaluation Hb_T and S_{O2T} are printed by the printer 27 in the step SP65. The buzzer 30 issues an alarm when the results of measurement become lower than predetermined levels when the patient is being monitored.

As described above, according to the embodiment of the present invention, light pulses of the wavelength the absorbance of which is considerably changed by a change in oxygen saturation of hemoglobin in blood of the tissue of the living body, and the light pulses the absorbance of which is not changed, and the light pulses the absorbance of which is changed to a small extent by changes in the quantity of hemoglobin and the oxygen saturation are applied at the predetermined levels from the positions near the light receiving portion and the position a little distant therefrom, and the light pulses reflect d through the tissue are detected, whereby the oxygen saturation of hemoglobin in blood of the tissue and the quantity of hemoglobin are evaluated based on the predetermined functions. Consequently, it becomes possible to solve various problems in the conventional non-invasive oximeters, such as incapability of measurement in a part where a pulsation component does not exist, measurement limited only to oxygen saturation of artery, occurrence of noise due to sway or vibration of a sensor, or incapability of measurement in the case of nonexistence of an optical cuvette for an optical transmission method. Therefore, the present invention makes it possible to evaluate lung functions, heart functions, conditions of oxygen supplied to the tissue, and other data in examinations of anesthesiology, dermatology, pediatrics or the lik , and to continuously monitor a patient for a long period.

Although the present invention has been described and illustrated in detail, it is clearly understood that the same is by way of illustration and example only and is not to be taken by way of limitation, the spirit and scope of the present invention being limited only by the terms of the appended claims.

Claims

1. A reflection type oximeter comprising:

beam sourc means (11 to 16) for applying, to a tissue of a living body, first and second beams of a wavelength involving a change in absorbance due to a change in oxygen saturation of hemoglobin in blood of said tissu , third and fourth beams of another wavelength involving no change in absorbance, and fifth and sixth beams of a further wavelength involving a relatively small change in absorbance due to changes in a quantity of hemoglobin and oxygen saturation,

beam receiving means for detecting said first, second, third, fourth, fifth and sixth beams reflected from said tissue,

evaluation means for evaluating intensities of said first, second, third, fourth, fifth and sixth beams reflected from said tissue based on an output of said beam receiving means and evaluating the quantity of hemoglobin in said tissue based on a predetermined function, and

output means (26,27) for outputting results of the evaluation of said evaluating means.

2. A reflection type oximeter in accordance with claim 1, further comprising

mode selection means (282, 283) for selection between a calibration mode for performing calibration to set the intensities of the beams emitted from said beam source means within predetermined ranges and a measurement mode for evaluating the quantity of hemoglobin in said tissue by said evaluation means.

3. A reflection type oximeter in accordance with claim 2, further comprising

voltage setting means (21, 22) for setting a voltage to be applied to said beam source means in response to selection of the calibration mode by said selection means, to cause the intensities of the first to sixth beams emitted from said beam source means to be within the predetermined ranges.

4. A reflection type oximeter in accordance with claim 1, further comprising

means (23) for calculating an average value of signals of each of said first to sixth beams received by said beam receiving means by a plural number of times,

said evaluation means including means (23) for evaluating the quantity of hemoglobin in said tissue based on said average value and a predetermined function.

5. A reflection type oximeter in accordance with claim 1, wherein

said beam source means comprises first to sixth beam sources for emitting said first to sixth beams,

said first, third and fifth beam sources are located at positions distant from a center of said beam receiving means by a predetermined distance d1, and said second, fourth and sixth beam sources are located at positions distant from the center of said beam receiving means by a predetermined distance d2, with a relation of $d1 < d2$ being maintained.

6. A reflection type oximeter in accordance with claim 1, wherein

said evaluation means comprises means for evaluating the quantity of hemoglobin in said tissue by the expression:

$$C1[\log(P3/P4)]^2 + C2\log(P3/P4) + C3$$

where P1, P2, P3, P4, P5 and P6 are the intensities of the first, second, third, fourth, fifth and sixth beams reflected from said tissue, respectively, and C1, C2 and C3 are correction values.

7. A reflection type oximeter comprising:

beam source means (11 to 16) for applying, to a tissue of a living body, first and second beams of a wavelength involving a change in absorbance due to a change in oxygen saturation of hemoglobin in blood of said tissue, third and fourth beams of another wavelength involving no change in absorbance, and fifth and sixth beams of a further wavelength involving a relatively small change in absorbance due to changes in a quantity of hemoglobin and oxygen saturation,

beam receiving means (17) for detecting said first, second, third, fourth, fifth and sixth beams reflected from said tissue,

evaluation means (23) for evaluating intensities of said first, second, third, fourth, fifth and sixth beams reflected from said tissue based on an output of said beam receiving means and evaluating the oxygen saturation of said tissue based on a predetermined function, and

output means (26, 27) for outputting results of the evaluation by said evaluation means.

8. A reflection type oximeter in accordance with claim 7, further comprising

mode selection means for selection between a calibration mode for performing calibration to set the intensities of the beams emitted from said beam source means within predetermined ranges and a measurement mode for evaluating the oxygen saturation of said tissue by said evaluation means.

9. A reflection type oximeter in accordance with claim 8, further comprising

voltage setting means (21, 22) for setting a voltage to be applied to said beam source means in response to selection of the calibration mode by said selection means, to cause the intensities of said first to sixth beams emitted from said beam source means to be within the predetermined ranges.

10. A r flection type oximeter in accordance with claim 7, further comprising

means (23) for calculating an average value of signals of ach of said first to sixth beams received by said beam receiving means by a plural number of times,

said evaluation means including means (23) for valuating the oxygen saturation of said tissue based on said average value and said pr determined function.

11. A reflection type oximeter in accordance with claim 7, wherein

said beam source means comprises first to sixth beam sources for emitting said first to sixth beams,

said first, third and fifth beam sources are located at positions distant from a center of said beam receiving means by a predetermined distance d1, and said second, fourth and sixth beam sources are located at positions distant from the center of said beam receiving means by a predetermined distance d2, with a relation of d1 < d2 being maintained.

12. A reflection type oximeter in accordance with claim 7, wherein

said evaluation means comprises means for evaluating the oxygen saturation of said tissue by the expression:

$$A - B \cdot \log\left(\frac{P1/P2}{P5/P6}\right) \Big/ \log\left(\frac{P3/P4}{P5/P6}\right)$$

where P1, P2, P3, P4, P5 and P6 are the intensities of the first, second, third, fourth, fifth and sixth beams reflected from said tissue, respectively, and A and B are correction values.

13. A reflection oximeter comprising:

beam source means for applying, to a tissue of a living body, first and second beams of a wavelength involving a change in absorbance due to a change in oxygen saturation of hemoglobin in blood of said tissue, third and fourth beams of another wavelength involving no change in absorbance, and fifth and sixth beams of a further wavelength involving a relatively small change in absorbance due to changes in a quantity of hemoglobin and oxygen saturation,

beam receiving means for detecting said first, second, third, fourth, fifth and sixth beams reflected from said tissue,

setting means for setting intensities of the beams emitted from said beam source means to predetermined levels,

evaluation means for evaluating intensities of said first, second, third, fourth, fifth and sixth beams reflected from said tissue based on an output of said beam receiving means and evaluating the quantity of hemoglobin and the oxygen saturation of said tissue based on a predetermined function, and

output means for outputting results of the evaluation by said evaluation means.

14. A reflection type oximeter in accordance with claim 13, wherein

assuming that the intensities of the first, second, third, fourth, fifth and sixth beams reflected from said tissue are represented as P1, P2, P3, P4, P5 and P6, respectively,

said evaluation means evaluates the quantity of hemoglobin of said tissue by the expression:

$$C1[\log(P3/P4)]^2 + C2\log(P3/P4) + C3$$

where C1, C2 and C3 are correction values, and

evaluates the oxygen saturation of said tissue by the expression:

$$A - B \cdot \log\left(\frac{P1/P2}{P5/P6}\right) \Big/ \log\left(\frac{P3/P4}{P5/P6}\right)$$

where A and B are correction values.

FIG.1

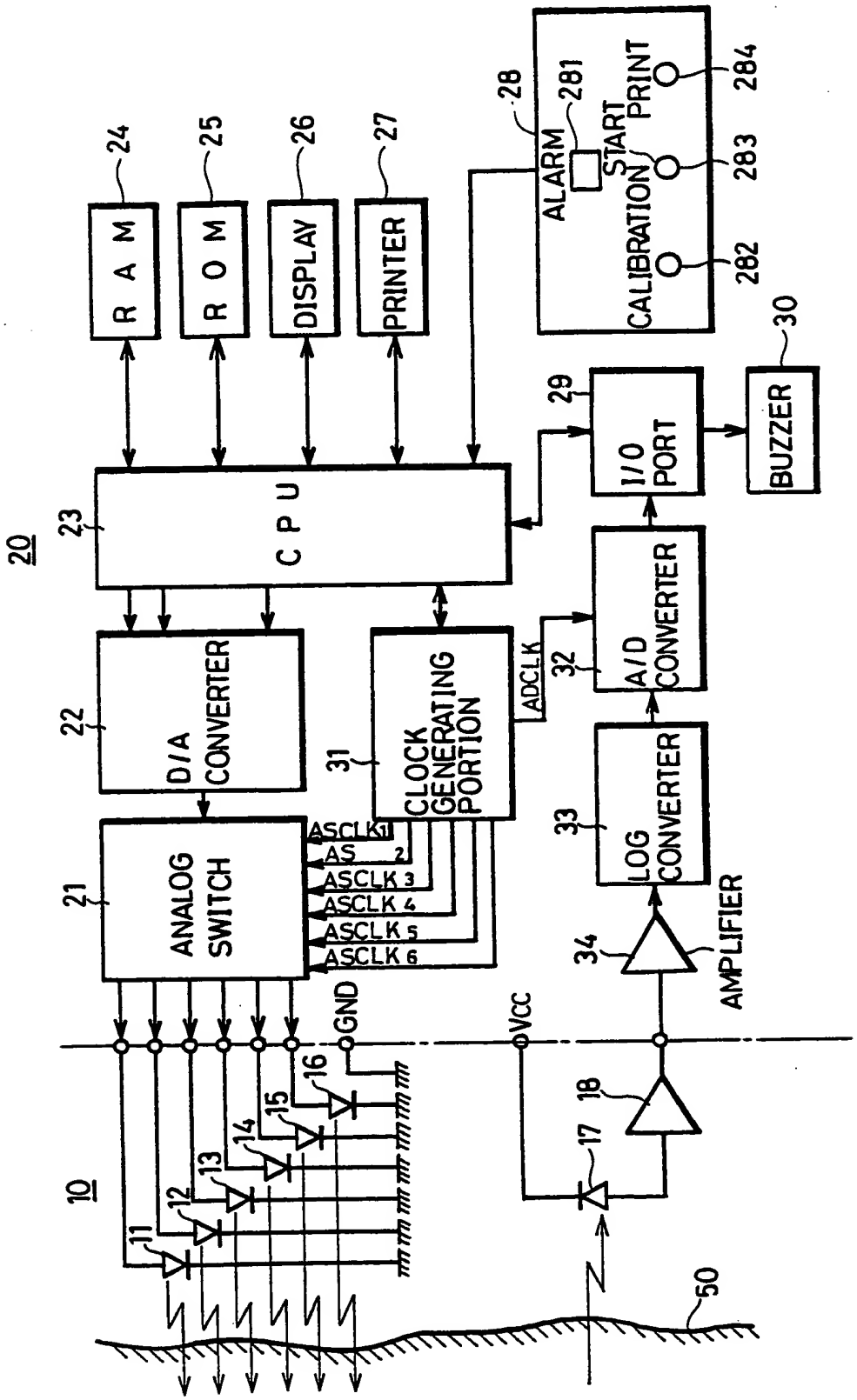

FIG.2A

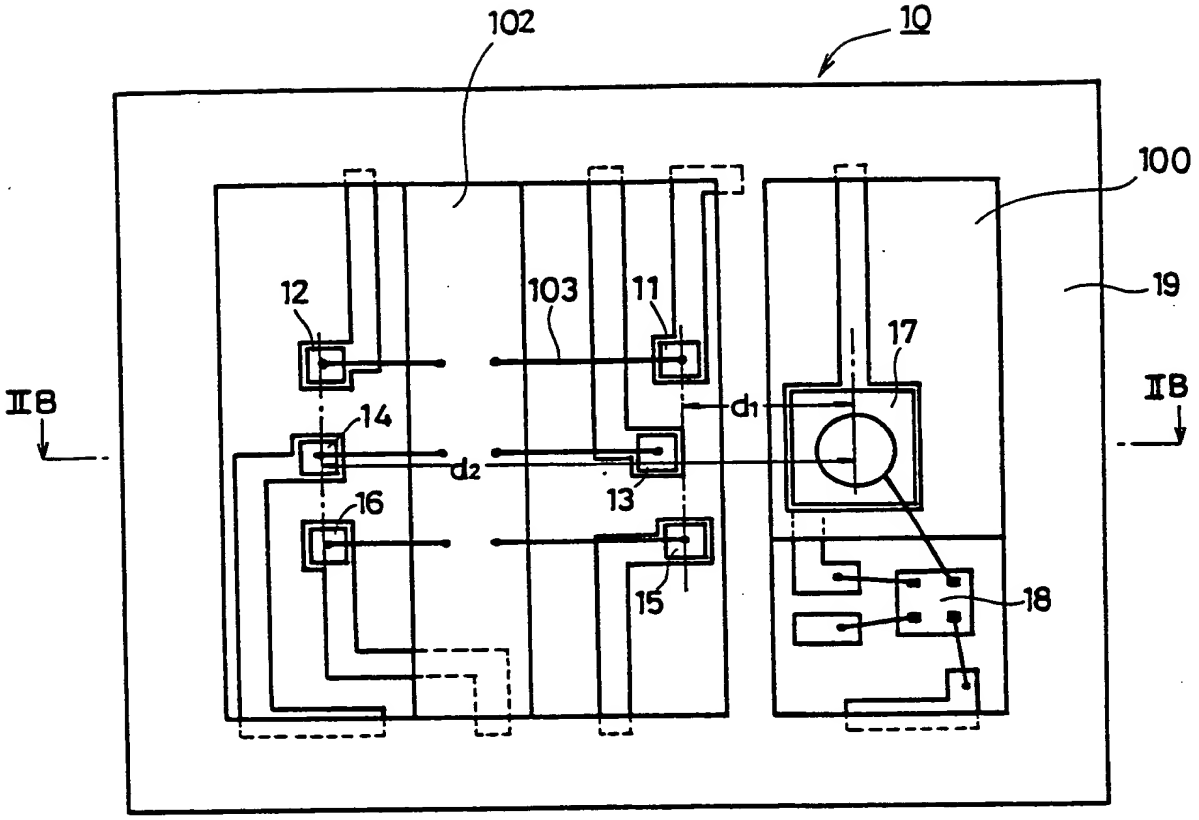

FIG.2B

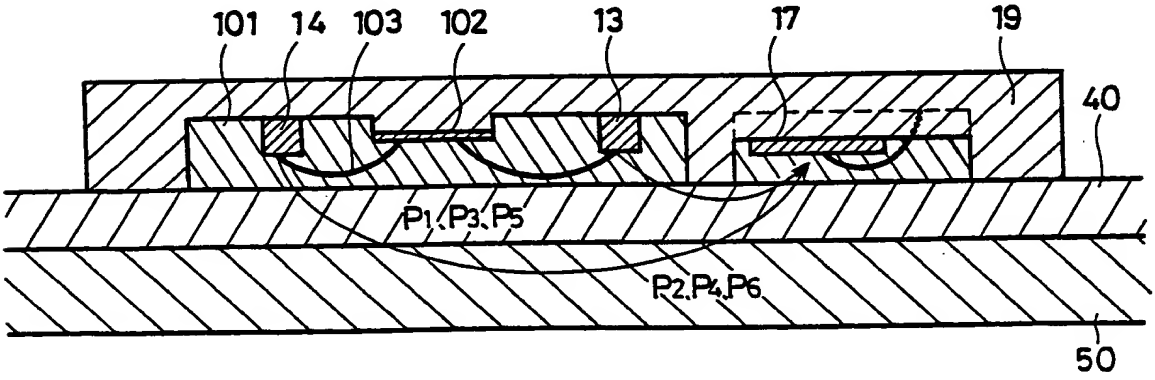

FIG.3

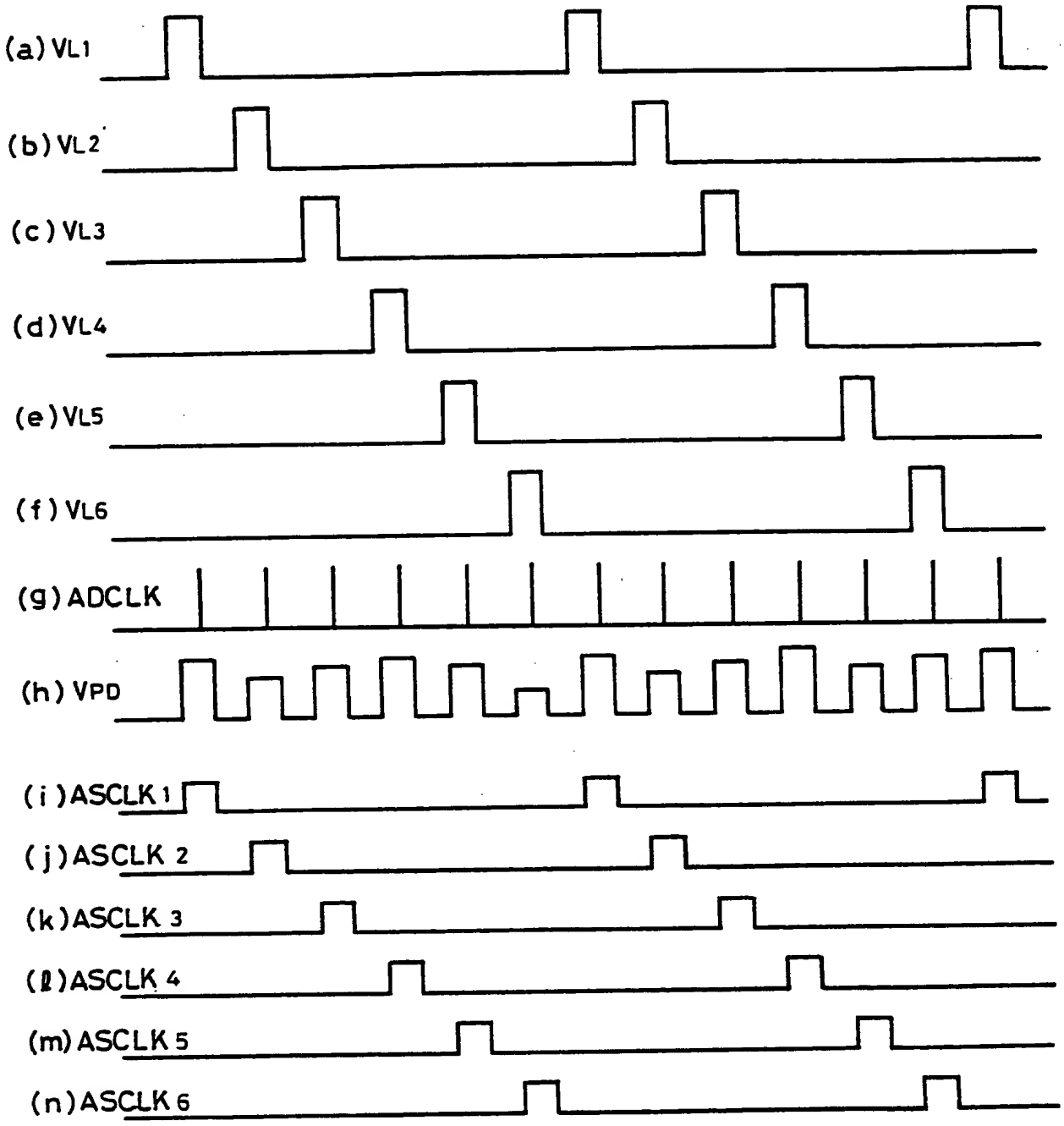

FIG.4

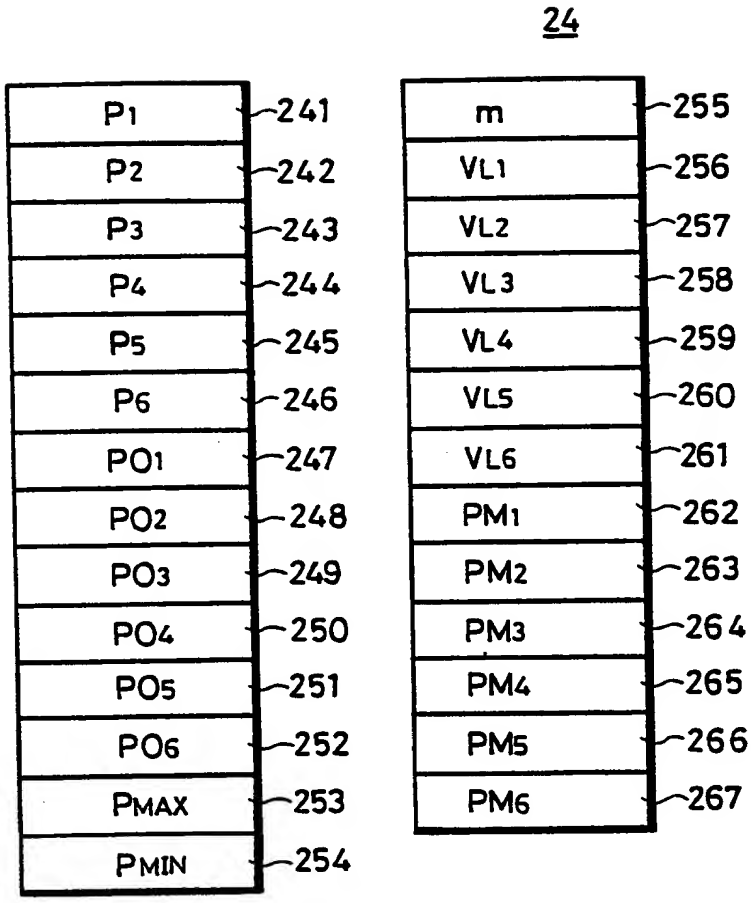

FIG.5

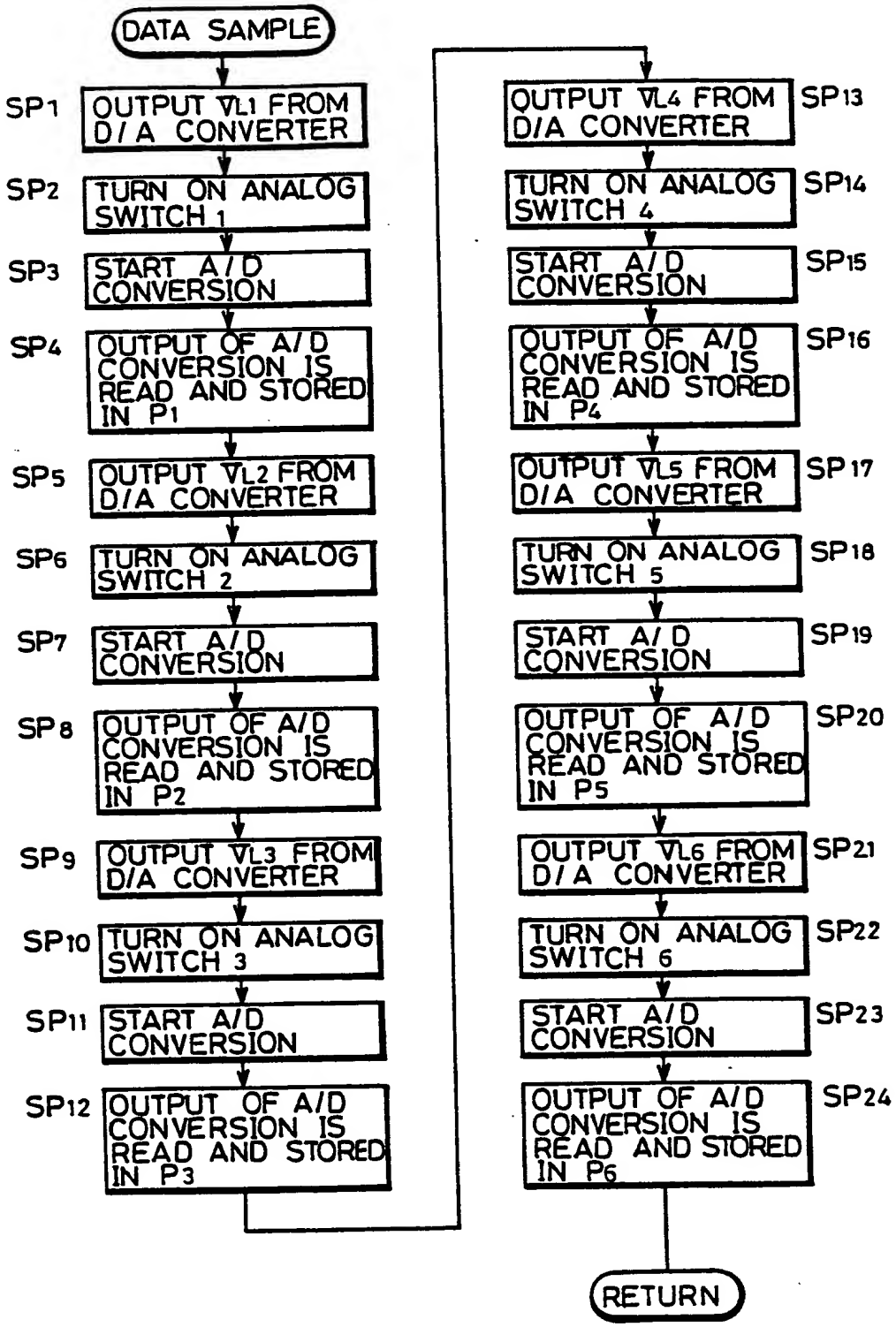

FIG.6

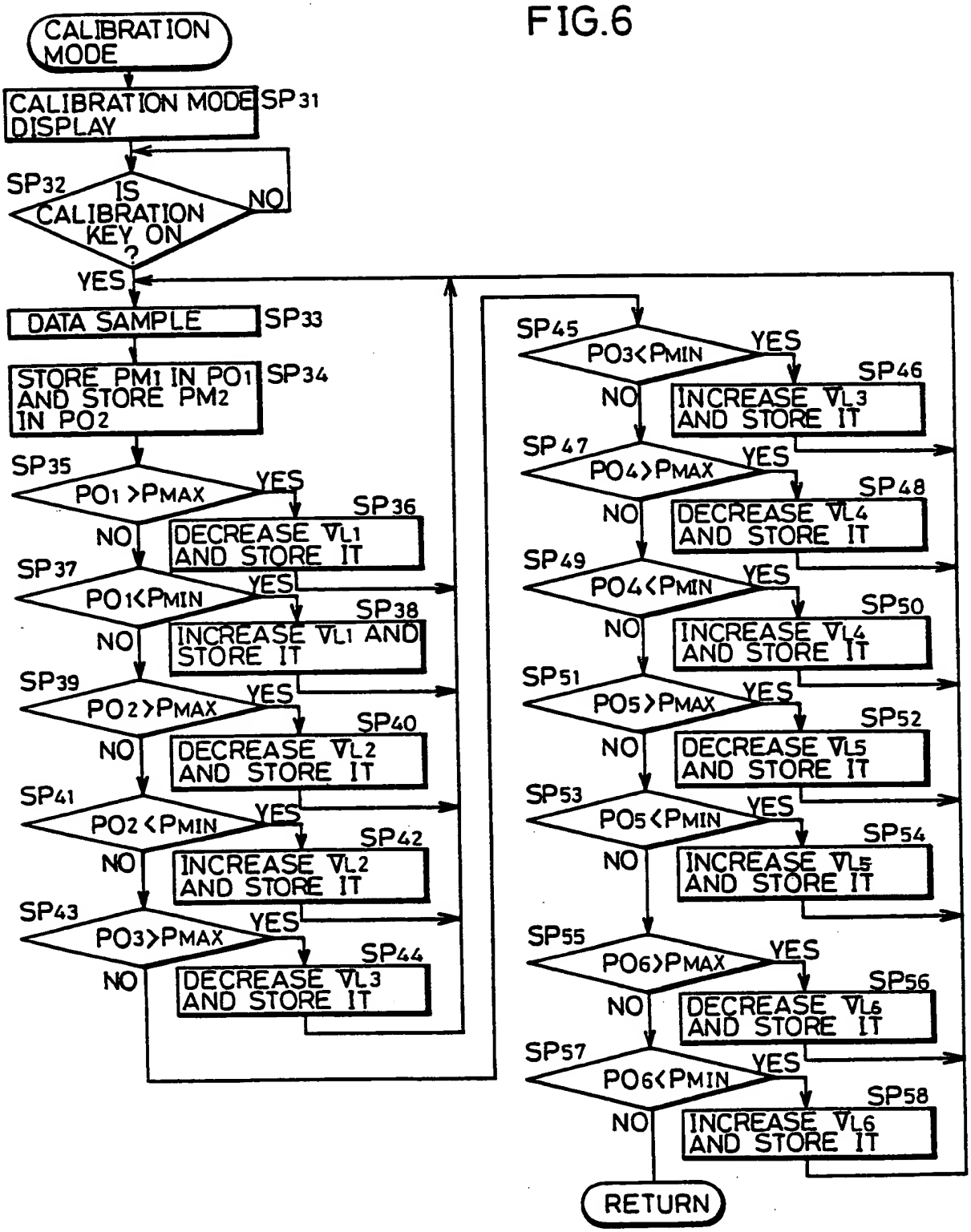

FIG.7